

Biogeosciences Discuss., author comment AC2
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Reply on RC2

Sergey N. Vorobyev et al.

Author comment on "Fluvial carbon dioxide emission from the Lena River basin during the spring flood" by Sergey N. Vorobyev et al., Biogeosciences Discuss.,
<https://doi.org/10.5194/bg-2021-109-AC2>, 2021

REVIEWER: The reviewer No 2 correctly argued that 'some of the drawn conclusions are lacking proof, and likely overestimate the annual carbon emissions.'

RESPONSE: We revised our conclusions and estimations, following his/her detailed comments below.

REVIEWER: Comment to line 167-169. A fixed k_{CO_2} value for the entire open water season of 4.6 m day^{-1} is rather high, especially since floating chambers often overestimate the fluxes (Long et al., 2017; Ribas-Ribas et al., 2018). Particularly when using floating chambers during the freshet, where the water velocity and turbulences are several times above the summer low which then lasts for 4 to 5 months. Used reference measured a median of $4,464 \text{ m d}^{-1}$, which were all sampled during June. In addition, since many k measurements were made, I would suggest separating main stems and tributaries. Also, when looking up the k values from the given ref. Serikova et al., all reported k values were given in $\text{cm}^{-1} \text{ h}^{-1}$, ranging between 5.1 and $16.5 \text{ cm}^{-1} \text{ h}^{-1}$ (which is 1.2 to 4 m day^{-1}). Please double check that the proper k value unit was used.

RESPONSE: This is very pertinent comment. In our calculations, we used a fixed value of 4.464 m d^{-1} as recommended for the Ob River by Karlsson et al. (2021). This river is similar to Lena in size, but exhibits lower velocity and turbulence than those of the Lena River. In fact, due to more mountainous relief, the Lena River main stem and tributaries have much higher turbulence than that of the Ob River and tributaries and as such this estimation can be considered rather conservative. Decreasing the k to even more conservative value of 3 m d^{-1} (which is the lowest range of world's rivers as recommended by Raymond et al., 2013) provide the values of specific emissions which are 30 to 50% lower than those obtained in this study ($k = 4.464 \text{ m d}^{-1}$). The resulted corrections in aerial emissions yield the from value ranging between 0.8 and $1.5 \text{ g C m}^{-2} \text{ d}^{-1}$ corresponding to total value of 4 to 7.5 Tg C y^{-1} . For convenience, we attached the revised tables to this response (Tables R1 and R2). Note that main stem and tributaries are always separated in the text, figures and tables (see Tables 1 and 2).

REVIEWER: Comment to section 3.4 on aerial emissions. As your own data shows, there

are strong temporal and spatial variability in pCO₂ levels.

RESPONSE: We do not completely agree with this statement. As we show in our work, the pCO₂ in Lena and tributaries remain generally stable over the night and day period (Abstract, Fig. 4, Fig. S2). The local lateral variability over the tributaries and across the channel is also low (Fig. S1B, Fig. S3). The global variability in pCO₂ over the largest part (~2400 km) of the main stem is "only" ±20% (from 800 to 1200 μatm, see Fig. 2 A). The variability of pCO₂ in the tributaries is indeed, higher (from 600 to 1100 atm) and this explicitly taken into account during our overall estimations of C emissions.

REVIEWER: Upscaling spring flood concentrations, where >50% of annual water masses discharges, for the remaining 4 summer months is highly uncertain. Summer concentrations from e.g. the Kolyma are reported to be 0.35 g C m⁻² d⁻¹. Also, in line 266 you report that 5022 km² water area are seasonal. This area needs to be removed when calculating the areal summer fluxes.

RESPONSE: We agree with sizable uncertainty on our estimations, which amounts to ca. 50% (from 1 to 2 g C m⁻² d⁻¹). We demonstrate, via analysis of available literature data, that seasonal variations of pCO₂ in the Lena River main stem do not exceed the range of our uncertainties (section 3.4, L 270-279). We do acknowledge sizable uncertainties on our first order estimations, especially in view of lack of direct pCO₂ data for the northern tributaries including a very large river Vilyi (L377-382). We further agree that rigorous aerial estimation should include 4 summer months with lower surface water coverage. However, introducing this correction changes the global value by less than 15% which is below the range of our uncertainties.

REVIEWER: Comment to line 358ff: What published data and I would like to see a table with this literature data. What are the numbers? If available with seasonal resolution as this is what you are comparing with.

RESPONSE: Extensive description of all the relevant literature data is provided in section 3.4, L 270-279. We believe that adding an explicit table will lengthen the paper and preferred to use the current format which is easier for the reader.

REVIEWER: Comment to the discussion section. Especially here English needs to be revised and restructured. Some parts can be shortened, while several other parameters which were introduced, were not discussed at all.

RESPONSE: We agree and reorganized these sections and revised the English. The three parameters of the river water chemistry (pH, DOC and DIC) were indeed, only partially discussed in the manuscript (L320-321, Fig. S6A). The correlation of pCO₂ with DIC and pH was not pronounced (see attached Fig. R1 A). The pH did not control the CO₂ concentration in the main stem, and only weakly impacted the CO₂ in the tributaries (Fig. R1 B). The latter could reflect an increase in pCO₂ in the northern tributaries which exhibited generally lower pH compared to the SW tributaries; the latter draining through carbonate rocks. Overall, such low correlations of CO₂ with DIC and pH reflected generally low predictive capacity to calculate pCO₂ from measured pH, temperature and alkalinity as stated in L 280-281: the ratio of calculated to measured pCO₂ was 0.67±0.15 (n = 47). This, again, demonstrates highly dynamic and non-equilibrium behavior of CO₂ in the river waters, with possible local hot spots from lateral input of CO₂-rich soil or suprapermafrost

waters. For these reasons, in-situ, high spatial resolution measurements of CO₂ concentration in rivers such as those reported in this study of the Lena Basin, are crucially important for quantifying the C emission balance in lotic waters of high latitudes.

REVIEWER: Figure 1 and S1 A: Since you have graticules, you do not need a north arrow. Actually, your north is not always "up" on the figures. Please remove them.

RESPONSE: Agree and edited accordingly.

REVIEWER: Figure S1 A: Change Landscape to Landcover map. Also, reference for this data.

RESPONSE: Agree and edited accordingly. The land cover information sources are described in section 2.4 (L183-191) and we will present them in the Figure caption of revised version.

REVIEWER: Figure 2. This data is very interesting, but what I am missing is the discussion on that. Are the peaks where conflux occurs? Higher fluxes due to turbulences? More information on differences between the tributaries.

RESPONSE: This is a good point. We do not have straightforward explanation for peaks shown on the diagram of the main stem. These peaks are not necessarily linked to CO₂-rich tributaries but likely reflect local processes in the main stem, including lateral influx from the shores and shallow subsurface waters, typical for permafrost regions of forested Siberian watersheds (i.e., Bagard et al., 2011). Given that the data were averaged over 20-km distance, these peaks are not artifacts but reflect local heterogeneity of the main stem (turbulences, suprapermafrost water discharge, sediment resuspension and respiration. Note that such a heterogeneity was not observed in the tributaries, at least at the scale of our spatial coverage (see Fig. S2, S3).

Bagard, M. L.; Chabaux, F.; Pokrovsky, O. S.; Viers, J.; Prokushkin, A. S.; Stille, P.; Rihs, S.; Schmitt, A. D.; Dupre, B. Seasonal variability of element fluxes in two Central Siberian rivers draining high latitude permafrost dominated areas. *Geochim. Cosmochim. Acta* 75, 3335-3357, 2011.

The differences between tributaries (presentation of results and their discussion) make the central part of our study, and this information is provided in section 3.3. and 4.1.

REVIEWER: Table 1: CH₄ concentrations are illustrated twice. Please remove or exchange one.

RESPONSE: Thanks a lot for catching this! Instead of 2nd CH₄ column, we will add the

FCO₂ calculated for most conservative scenario of $k = 3 \text{ m d}^{-1}$.

REVIEWER: Organic C and OC, choose one and use consistently.

RESPONSE: We homogenized as OC.

REVIEWER: Additional data from tables (DIC, pH) not really discussed and incorporated.

RESPONSE: The correlations of pCO₂ with DIC and pH were poorly pronounced (see response above and Fig. R1) and as such neither DIC nor pH could serve as sole controlling factors of CO₂ concentration in the Lena River main stem and tributaries.

Please also note the supplement to this comment:

<https://bg.copernicus.org/preprints/bg-2021-109/bg-2021-109-AC2-supplement.pdf>